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Transferring advanced physics research tools to education: how to teach simulation tools used in radiation physics research to university students

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TRANSFERRING ADVANCED PHYSICS RESEARCH TOOLS TO EDUCATION: HOW TO TEACH SIMULATION TOOLS USED IN RADIATION PHYSICS RESEARCH TO UNIVERSITY STUDENTS

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Abstract

At the Centre of Medical Radiation Physics (CMRP), School of Engineering Physics, Faculty of Engineering, at the University of Wollongong (UOW), we are implementing a hands-on computing laboratory, commencing in autumn 2010, to teach scientific computing methods and modern, advanced research tools for radiation physics to postgraduate and undergraduate students. Engaging undergraduates and postgraduates together in work with a tool widely used in research laboratories is a unique development, and represents the articulation of the University's commitment to the enhancement of the teaching/research nexus, and to the development of learning communities. The object of the laboratory is to teach students how to use Geant4 in the study of radiation physics related problems. Geant4 (www.cern.ch/geant4) is a Monte Carlo Simulation Toolkit, describing the interactions of particles with matter. It is widely used in research laboratories all over the world, from High Energy Physics to medical physics and space science. While the Geant4 Collaboration organizes courses all around the world to familiarise researchers and postgraduates with the Toolkit, insufficient attention is paid to undergraduates. The objectives of our program are that, upon completion of the practical laboratory, the students will be familiar with radiation physics and its applications, software development methods, computing instruments for research, the Monte Carlo approach, and the C++ language. They will also have had a unique opportunity to improve their problem solving skills and research methodologies.

The design of the Geant4 hands-on lab faces two important issues: the heterogeneous computing skills and differing knowledge of radiation physics amongst students. Independent of their education grade, students have different expertise with programming, and computing matters in general. This problem can easily be overcome as Geant4 is developed for use by those with minimal computing expertise. However, the correct use of Geant4 requires a deep knowledge of radiation physics; this poses the second issue faced. The higher levels of motivation of postgraduate students will be one factor supporting undergraduates, in that working with Geant4 should foster a learning community, with peer learning and teaching occurring, and also provide undergraduates with a sense of future. Furthermore, we think we can overcome the problem of lower levels of knowledge through designing a guided hands-on course, providing Geant4 simulation exercises for students, based on their level of preparation. This course has high potential to increase the commitment of students towards radiation physics.

Keywords - Teaching/Research nexus, radiation physics research, undergraduate education, Geant4.

1 INTRODUCTION

Given the continuous, rapid evolution of scientific knowledge and technology, it is crucial to teach university physics students modern and advanced scientific computing tools. With this in mind, the Centre of Medical Radiation Physics (CMRP), School of Physics, University of Wollongong (UOW), is implementing a hands-on computing laboratory to teach scientific computing methodologies and modern, advanced research tools for radiation physics to both undergraduate and postgraduate students.

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Geant4 [1-3] describes the interactions of particles with matter, and is widely used in research laboratories all over the world, from High Energy Physics (HEP) to medical physics and space science. It adopts object-oriented technology, and it is implemented in the C++ programming language. It is developed, maintained, and upgraded through international collaboration, spanning the US, Europe, Asia and Australia. While the Geant4 Collaboration organizes courses and seminars all around the world to familiarise researchers and postgraduates with the Geant4 Simulation Toolkit, insufficient attention is paid to undergraduates. The common practice in the international academic world is to delegate the teaching of scientific computing tools to research centres, where students work on their Honours/Masters/PhD thesis. This strategy poses the risk that students may be isolated in their learning process, causing frustration and lack of efficiency. It is important to introduce students to advanced research tools early in their university career, with the unique opportunity to get in touch with the issues and methods typical of the research world. At CMRP, Geant4 is intensively used as a Monte Carlo Toolkit to study novel concepts of detectors for radiation protection [4-6] and imaging [7], and to study methodologies to enhance radiotherapy treatments [8-9]. The CMRP accounts for approximately forty students (Masters/Honours and PhD) each year, with approximately one third using Geant4 as a simulation toolkit in their research.

Considering this situation more broadly, concern has increased both as to whether universities have been failing their undergraduate populations in terms of fostering their research capacities and building academic and professional futures, from differing perspectives [10-11]. UOW articulated its position on the nexus between teaching and research in December 2008 [12]. The aim is, through attention to the connection between learning, teaching and research, to provide students with professionally and academically relevant skills, attitudes and ways of thinking; stimulate discussion and debate; promote understanding of the ways in which researchers work; and encourage students to pursue higher degrees by research. The issue is, then, how this particular nexus is expressed in radiation physics, and whether and how it has the potential to enhance the students' learning.

According to the Boyer Commission [10], 'research universities are often archipelagos of intellectual pursuit rather than connected and integrated communities', whereas what is needed is students at every level sharing with faculty members the adventure of discovery. Changing technologies have seen a sector-wide shift towards flexible learning, not necessarily towards an accompanying shift of faculty time towards classes where interaction with and between students is normal and integral. The model the Boyer Commission proposed involves scholar-teachers treating their research sites as seminar spaces open to graduate and undergraduate students, where, regardless of academic level, all can practice their research skills and help develop others' proficiency. Students perform their understanding, rather than just declaring it [13]. The approach being used in radiation physics is an example of this model in action.

In this instance, radiation physics practice frames the curriculum, with undergraduate learners learning most effectively alongside other learners in and through practice [14]. Broad access to mature practice should provide opportunities for self-evaluation without tests, praise or blame; talk within practice (sharing information that progresses activities) and talk about practice (stories about problematic cases) should engage, focus and shift attention, engender coordination, support reflection, and signal membership of a research community [14].

Based on these principles, the course will be introduced in autumn session 2010 (March-June 2010), within radiation physics courses PHYS366 and PHYS952. The organisation of this hands-on course takes inspiration from our previous experience as lecturers in Geant4 Collaboration hands-on courses for researchers, organised by research institutes as workshops of a few days. The curriculum we have designed incorporates the following:

- pairing postgraduate and undergraduate students as they undertake laboratory work;
- intensive support from academic staff for students during laboratories;
- identifying aspects of Geant4 that require formal teaching, and incorporating these in seminars that intersperse with laboratory work;
- elaboration of a scientific report, as final summative assessment, describing the articulation of the project developed within the Geant4 hands-on laboratory.

Engaging undergraduates and postgraduates together in developing a scientific project, with a tool widely used in research laboratories, is a unique development, and represents the articulation of the University's commitment to the enhancement of the teaching/research nexus and to the development of learning communities. The object of the hands-on laboratory is to teach students how to use the Geant4 Simulation Toolkit [1-3], in studying radiation physics related problems. The course will be focused on the Geant4 simulation Toolkit, but could be extended to other Monte Carlo codes, using the same method, and to other computing tools for scientific research.

2 METHODOLOGY

The project grew out of reflection on our teaching and students' learning, and the desire to improve the situation in the light of the contemporary professional and university context. Our new approach to developing the research skills of undergraduates alongside more experienced students and active researchers has been developed using an action research process [15]. Action research is not a 'method' or 'procedure' for research, but a series of commitments to observe and problematise practice in the light of the principles of social enquiry [16]. It involves a cyclical process of observation, problem posing, data gathering, reflecting, planning and implementing actions – a search to improve practice rather than solve a problem.

The starting points were seminars and hands-on courses for researchers, and feedback received on these. These experiences showed that theoretical seminars on Geant4 are not as successful as hands-on courses, as the content of the seminar is usually complex for non-computing experts, in most of the cases introducing too many new concepts, with the result that the learning process is superficial. Yet, learning to use computing tools is a natural experimental activity for students with a scientific background. We believe that the first approach to computing tools should be experimental. In depth, theoretical information should be provided in a second stage.

We had observed that postgraduate and Honours students experienced the learning of Geant4 very differently, and so, at the end of 2009, we conducted a survey, asking CMRP students about their computing background (as related to physics research) at the beginning of their thesis project, and the level of difficulty they faced in learning to use Geant4. We found that students starting their Masters/Honours thesis generally lacked a computing background suited to scientific research, and found it very hard to start working with Geant4. Amongst PhD students, there was more heterogeneity in scientific computing knowledge (from low to highly qualified), and, independently of their computing background, students encountered fewer obstacles in learning to use Geant4. The findings stressed that, even if Geant4 is developed for use by those with no computing expertise, students will have considerable difficulty in starting to use it as a simulation toolkit. We think that this is not a problem specific to Geant4, but is intrinsic to the understanding of any Monte Carlo simulation tool for radiation physics, and, indeed, of any advanced computing tool for research that will be used by those who are not computing experts.

The survey highlighted the need to design a course for both undergraduate and postgraduate students that would teach the rigorous method associated with using properly advanced simulation tools for radiation physics. In our experience, students encounter more difficulties in learning Monte Carlo codes at the very beginning, when they need (1) to grasp the basic knowledge, to get a global vision of the structure of the Monte Carlo code kernel, and (2) to learn how to set-up a specific simulation application. In this early stage, students are quicker in their learning process if they are closely supervised by a Monte Carlo expert. Once students get past the uncomfortable feeling of the first approach, the learning process speeds up considerably, requiring no close expert supervision. These observations strongly supported the choice of a hands-on course, where students start from scratch, with no preliminary computing knowledge assumed, and are required to develop a Geant4 simulation, during the laboratory sessions, under the close supervision of Geant4 experts as laboratory tutors.

The practical computing sessions will be spaced out with seminars providing the fundamental introduction to Geant4 and to the hands-on course, supported by discussion sessions (see section 3). There will be four consecutive Geant4 hands-on sessions, each of three hours, with students practicing at home between sessions. The students will work in groups of two people (section 3.2) to stimulate active participation. Through this process, students will enhance their problem solving skills and practice scientific method for research. At the end of the session, students will present their work to peers and academic staff of CMRP.

As this hands-on laboratory is proposed for the first time at UOW as part of a university course, a feedback form will be filled by the students at the end of the laboratory, about their learning experience, to improve the overall design of the hands-on laboratory.

3 STRUCTURE OF THE COURSE

3.1 Seminars

Seminars will consist of an introduction to the hands-on laboratory, and a detailed description of the project the students will develop. The Geant4 simulation toolkit functionality and its applications in various domains of radiation physics research (HEP, space science, medical physics) will be presented. Essential insights concerning the methods needed for developing sound and robust software systems for their project will also be provided [17].

Seminars concerning the fundamental Geant4 background necessary for solving the Geant4 exercises will be provided before each practical computing session. More in depth information may be provided to students in a second stage, after they grasp the basics of the use of Geant4. Our experience in Geant4 education indicates that the explanation in one seminar of too many concepts – usually completely new to the audience – may cause frustration and a high risk of unsuccessful outcomes.

3.2 Definition of working groups

The correct use of Geant4 requires a deep knowledge of radiation physics. Undergraduates and postgraduates typically have a significantly different level of knowledge of radiation physics, and, as mentioned previously, postgraduates are often more committed to their studies. Our strategy consists of mixing undergraduate and postgraduate students in the same team. This runs the risk of unbalancing the team, with the postgraduate students as leaders and primary actors. However, we expect that, by working with others who have experience and skill, and sharing in real undertakings in which there is a clear relationship between means and consequences [18], the undergraduate students will become more engaged with their studies, develop a vision of the future, and be more challenged to do their best. It has been established that tasks requiring a relatively high level of cognitive engagement are perceived as interesting and enjoyable, regardless of skill level [19].

Our strategy consists in forming working groups of two students at each workstation. The teams are formed by the Geant4 coordinator, considering two aspects: the computing background and the study level of the students (undergraduate/postgraduate). Team members will have similar computing backgrounds. If there is a computing knowledge gap between the team partners, the biggest risk is that the experienced partner will do all the active work, while the second one will be passive, missing the most important outcome of the course. This would have a negative impact on teamwork, eventually causing frustration in the team members.

3.3 Laboratory work

During the hands-on course, students will develop a simplified Geant4-based dosimetric system for brachytherapy, through a series of exercises. Brachytherapy [20] is a radiation therapy treatment for prostate, cervix, uterus, and skin cancer. Radioactive sources are set directly in the tumour region, or in its proximity, delivering the required dose to the cancer, and preserving the surrounding healthy tissue. This project has been defined as core of the hands-on laboratory because it is a hot topic in current medical physics research [21-24], important for clinical procedures in the fight against cancer. This choice has also the advantage of providing insight in the world of medical physics, and to eventually motivate students to pursue a career in this direction.

Students will learn to develop the Geant4-based dosimetric system through a series of exercises, adopting an iterative-incremental approach [17]. The choice of providing a set of exercises to solve was dictated by the fact that students tend to put more effort in the study when they are challenged with problems to solve, in a field of interest. We have designed the set of exercises from the perspective that all the students have no computing background.

Students will be provided with a dummy Geant4 application at the beginning of the course. In each development cycle, corresponding to the solution of one exercise, the software system functionality will be refined. The user requirements will concern essential components of a typical Geant4 application: the modelling of (1) the experimental set-up and detector in terms of geometry and materials, of (2) the physics component in terms of particles and processes, of (3) the radiation field in terms of particle, position, direction and energy. Students will also learn to use the Geant4 user interface, to visualise the experimental set-up in terms of geometry components and particle tracks, and to store the results of the simulation in electronic analysis format.

Students will become familiar with the alternative and complementary Geant4 physics models, to describe the electromagnetic interactions of particles with matter, the Geant4 Standard and Low Energy Packages. The Geant4 Standard electromagnetic Package [25-26] provides a variety of models based on an analytical approach, to describe the interactions of electrons, positrons, photons, charged hadrons and ions in the energy range 1 keV–10 PeV. The Geant4 Low Energy Package [26-27] extends the coverage of electromagnetic interactions in Geant4 below 1 keV, an energy range that is not covered by the Standard Package. For this reason, the Geant4 Low Energy Package is addressed to describe in detail the interactions of particles in the low energy region, typical of medical physics applications. The Geant4 Low Energy Package offers two alternative model sets. One is based on a parameterised approach, using evaluated data libraries (EPDL97 [28], EEDL [29] and EADL [30]), and the second one consists of the re-engineering of the Penelope physics models [31], in Geant4.

The students will also learn the methods of testing the correct functionality of their Geant4 code.

3.4 Hands-on laboratory exercises

The core of the learning process of Geant4 is the hands-on practical computing activity, where students are required to develop the simulation code, under the strict supervision of, and with the support of, Geant4 tutors. For the success of this crucial component of the course, the active participation of all the students is required. In this phase, it is important to have laboratory staff, not only highly experienced with Geant4, but also very attentive to the students. Hands-on course staff must check that all the team members work actively and must provide significant support to the students in their project development, enhancing their problem solving skills through the stimulation of discussion and critical analysis of possible methods of solving a specific problem. Our previous experience with Honours/Masters students indicates that one expert is needed to follow a maximum of five working groups effectively.

The hands-on laboratory is designed as a set of four sessions, consisting of three hours each one. This may increase or decrease, depending upon feedback and the success of the course in terms of planned outcomes and achievements, as well as on the number of students who become interested in going into more depth in Monte Carlo simulation studies for physics research.

Four exercises are planned as a minimum requirement for successful outcome of the course. If some teams finish the exercises before the end of the course, with a significant margin of spare time, then other exercises may be included. The difficulty level of the exercises increases from low to high through the course, to challenge the students and to encourage them to use and improve their problem solving skills. However, the complexity of the exercises is designed to guarantee that all the students have the instruments to pursue a successful outcome in the course, independently of their specific computing background prior the start of the hands-on course.

The exercises cover the essential components of a typical Geant4 simulation (geometry, primary particles, physics processes). The method used to retrieve and analyse the result of the simulation (energy deposition and dose), by means of ROOT [32] (see section 4), will also be taught.

At the beginning of the course, the students are provided with a dummy Geant4 simulation application. Fig. 1 shows the experimental set-up of the simulation. A point-shaped, isotropic source of 1 MeV photons is set in the centre of a water box, subdivided in 1 mm wide voxels, along X, Y, and Z direction. The water box has been selected as geometry, as it is the model of a typical phantom used for dosimetry in medical physics studies. The Geant4 Low Energy Package has been selected to describe the interactions of electrons and photons, particles involved in the experimental set-up of the Geant4 brachytherapy application. The energy deposition and dose are calculated in the voxels of the water phantom, and stored in analysis objects (ntuples and histograms), in a ROOT file, output of the simulation. The application is provided with a simple user interface, to define parameters of the experimental set-up (i.e. number of photons to shoot as primary particles, energy of the emitted photons, etc.) in the simulation interactive sessions, or in macro files to be executed in batch mode.

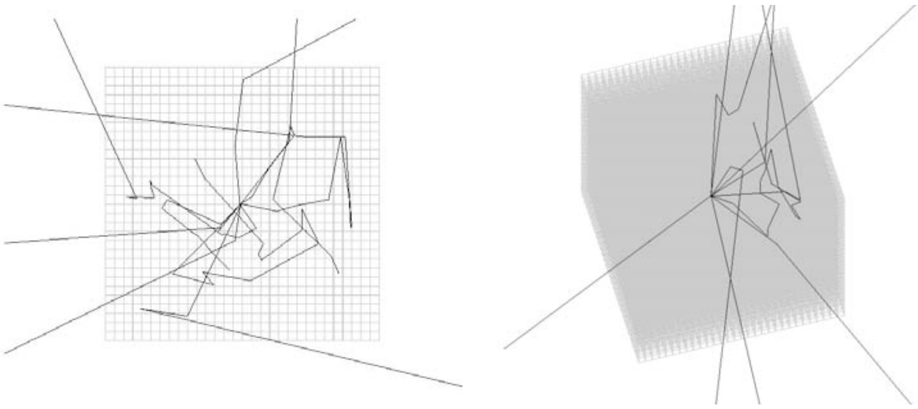

Fig.1: Experimental set-up of the dummy Geant4 application, provided to students at the beginning of the hands-on course, as starting Geant4 application, to work on. A 1 MeV photon isotropic, point-shaped source is set in the centre of a water phantom (size = 30 cm), subdivided in voxels, along the X, Y and Z direction. 10 events, corresponding to the generation of 10 photons (black tracks), were executed.

The application is interfaced to the OPENGL visualisation tool [33] (see section 4) to visualise the experimental set-up in terms of geometry components and particle tracks.

The first exercise the students will have to solve is to learn to compile and execute the Geant4 dummy application, in interactive and batch mode. They will learn to use the simulation user interface commands, in particular to change the parameters of generation of primary particles. They will become familiar with the use of ROOT, to be able to plot and analyse the results contained in the ROOT output file.

The second exercise will consist of modelling a ^{125}I permanent implant radioactive seed (Fig. 2), set in the centre of the water phantom. In order to do this, students will learn to model the materials and the geometry components of the radioactive source. The parameters of generation of the photons will have to be changed as well, in order to model the delivery of the primary particles from the radioactive core of the source. Students will verify the correct implementation of the geometry as they learn to use Geant4 geometry tools for debugging purposes. Students will store the parameters of generation of the photons (energy, primary vertex and direction) in a ROOT ntuple, to be analysed, to test the correct generation of primary particles.

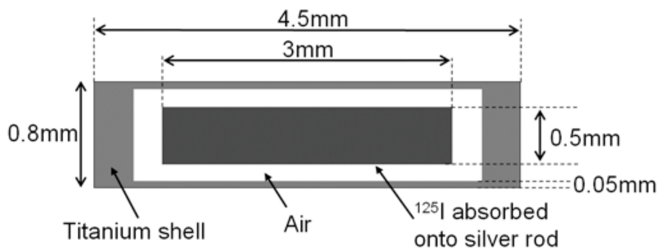

Fig. 2: Sketch of the brachytherapy ^{125}I source, model 6711, by Oncura [34].

In the third exercise, students will conduct an in depth study of alternative Geant4 electromagnetic approaches, describing the interactions of particles in matter. Students will learn to activate the alternative models (Standard Package, Low Energy Package with Livermore and Penelope approaches) in their Geant4 Physics List and analyse the effect of the specific physics model sets in the dosimetric results of their Geant4 simulation. Students will gain familiarity with the concept of *cut* [1-3], threshold of production of secondary particles, important to calculate accurately the energy deposition in a geometry component of interest of the experimental set-up. Students will describe how this parameter affects the dosimetric results of the simulation.

Finally, in the fourth exercise students will perform dosimetric simulations, analyse the results and report the data.

3.5 Hands-on laboratory assessment

For the successful outcome of this course, we believe that students should be assessed during the hands-on laboratory, and at the end of the course.

At the end of each laboratory session, there will be an open discussion among students and laboratory staff, concerning their activity in the laboratory, with a critical analysis of the achievements, results, obstacles experienced, and the method adopted to solve the exercises. This part of the session is highly useful for students to critically summarise what they learnt in the day, and stimulates them to reflect, and to improve their method in the next session. In our experience, it is in this part of the course where the most interesting questions and ideas from students arise, and where more in-depth information and important reflections take place, providing a good opportunity to engage the students more deeply in the project, and to provide guidelines to enhance their problem solving skills and use of research method.

The open discussion session concluding each hands-on laboratory will also help the tutors significantly in understanding how the learning process is proceeding, providing insights on the effectiveness of the course, common difficulties encountered by students in the learning process, student engagement in the subject, and active participation of all team members in the laboratory. Student feedback will also significantly help the laboratory coordinator to check any emergent issues, intrinsic to the new course design, such as inefficient organisation of time schedules, incorrect levels of difficulty of the computing exercises (i.e. too simple or too difficult), and inappropriate teaching strategies employed by the laboratory coordinator and tutors. Student feedback is also important to understand if there are unbalanced working groups.

At the end of the hands-on course, students will provide a final scientific report on the project, as summative assessment. In the final report, students will explain the aim of the project, the method of the study, the description of the developed software application for brachytherapy dosimetry, the results of the simulation study with their discussion, complemented by the description of testing procedures to verify the correct functionality of the software product.

3.6 Public seminar

At the end of the course we are organising a public seminar, especially addressing the students of this course, to illustrate the research projects developed at CRMP, adopting Geant4 as a simulation toolkit, with the goal of engaging students to extend their studies on Monte Carlo simulation codes, and – in a wider vision - to encourage them to pursue a career in research. At this stage students will have the Geant4 background necessary for understanding and appreciating the scientific content of this final seminar.

4 RESOURCES AND MATERIALS

The hands-on course will take place in a computing laboratory of the university, equipped with approximately ten workstations, as we envisage no more than twenty students enrolling in the course. Fewer workstations may be necessary if some students are equipped with private laptops.

The workstations will be connected with CMRP cluster. This cluster is normally used to execute Geant4 simulations for CMRP research projects. It is provided with all the software tools necessary for the hands-on course. The hardware and software tools are maintained and regularly upgraded. The cluster consists of 72 cores, ~3GHz CPU, 1 GB memory. Students will be provided with an account on the cluster, for the entire length of the course.

We decided to use pre-existing computing resources. This solution is also advantageous as minimum extra system management work is required to set-up the computing infrastructure for the Geant4 course, with respect to routine CMRP cluster management. Other strategies may be adopted in the future. For example, another solution may be to install all the required software tools directly on the workstations used in the university computing laboratory.

Two Geant4 experts will coordinate the hands-on laboratory and work as tutors, supporting the learning process of the students.

4.1 Computing infrastructure

All the software tools necessary for the Geant4 hands-on laboratory are freely downloadable from the web, and are summarised in Table 1. The Linux distribution of the CMRP cluster is CentOS [35]. Geant4 can be downloaded from the web page of the Geant4 Collaboration [3].

The installation of Geant4 requires the Class Library for High Energy Physics (CLHEP) [36]. CLHEP is a C++ library with HEP-specific foundation and utility classes such as random generators, physics vectors, geometry and linear algebra. CLHEP is structured in a set of packages independent of any external package. The Geant4 data files, downloadable from [3], are libraries of radioactive decay data, physics cross sections, and other physics data, necessary to model some interactions of particles in matter.

ROOT [32] is an object-oriented data analysis framework, developed at CERN, originally designed for the challenges of HEP data analysis. It adopts an Object-Oriented technology and C++ as programming language. ROOT can be integrated in Geant4 applications, to store the results of the simulations in analysis objects, as histograms and ntuples, in a ROOT output file. Users can then utilise the ROOT graphical user interface, to manipulate and plot the results of the simulations.

OpenGL [33] is a visualisation driver that can be interfaced to Geant4 and used as event display in Geant4 simulations, to visualise the simulation experimental se-up in terms of geometry components and particle tracks. OpenGL is distributed within CentOs.

Table 1: Software tools to install on the computing resources, for the Geant4 hands-on laboratory.

	Software tool
Platform	Linux – CentOs distribution
Compiler	gcc 4.1.2
Monte Carlo simulation tool	Geant4
Libraries	CLHEP, Geant4 data files
Analysis tool	ROOT
Visualisation tool	OpenGL

5 DISCUSSION AND CONCLUSIONS

We believe this new course has high potential to both engage students in radiation physics and to encourage them to pursue a career in research. The core of the learning process is the active participation of the students, with the development of a project of interest for research in medical physics, where discussion between students and Geant4 experts is encouraged. We strongly believe that the best, most engaging approach to teaching advanced computing tools for radiation physics and software development methodologies in a Physics School, where it is demonstrated students have scanty computing backgrounds, is to let the student learn through practical experience, with the goal of developing a project of interest for radiation physics research.

There are two major risks we face in implementing this new approach, all part of the action-research process. Firstly, the program is flexible and may eventually change on the fly, during the course itself. This risk is intrinsic to a course that encourages the active and interactive participation of the students, and builds in responsiveness to emergent needs. Another risk is that we may overload the students. This should be limited by the strong support of the Geant4 laboratory staff in the practical sessions of the laboratory, and the fact that we have designed the laboratories to incorporate the minimum number of exercises needed to gain a comprehensive vision of the basics of Geant4.

The success of this laboratory depends, we think, on very attentive laboratory staff, to individuate the deficiencies and strengths of each working group, to make sure that all the team members work actively, and to steer the learning process to enhance problem solving skills and critical analysis. We believe we will achieve this through building in regular feedback and discussion with students, as well as assessment processes that clearly link to the work-related activities they are undertaking. We are looking forward to put this first UOW Geant4 course in practice, to observe the reaction of the students, their engagement and interest in the subject, their feedback at the end of it, and the outcomes of the learning process.

In terms of future developments, besides the ongoing modifications and changes to course design, the issue of class size may also need to be addressed. This current version of the course is possible thanks to the limited number of students of School of Physics, where there are usually not more than thirty to forty students enrolled. The organisation of a hands-on course for bigger classes would be very challenging and may represent a future stage of this educational project, when, for example, a Geant4 hands-on workshop may be organised for students of various Australian universities. For the students who participate in the program, the Geant4 hands-on course will motivate undergraduate and postgraduate students to pursue a career in physics research, in universities, industries, in hospital medical physics centres, and in any other radiation physics research centre. It is also anticipated that this course will stimulate students to pursue higher degrees by research.

It is our belief that linking undergraduate, Honours and postgraduate students with each other through a research process represents a significant development in teaching, learning, research and professional practice. Within this course, students will learn scientific method to develop a research project, in a real case scenario. Our experience shows that such a challenge will engage and motivate students to put all their effort in the laboratory activity. This course will provide a solid ground to improve problem solving skills and teach software development methodologies, important in the business world, and the students will mature their knowledge in radiation physics as members of a growing learning community.

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